

Subsurface Vapor Intrusion into Buildings

(New and Revised Models)

US EPA RECORDS CENTER REGION 5



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Concerns have been raised about the potential for subsurface contamination in either soil or ground water adversely impacting indoor air quality. In September 1998, EPA developed a series of models for estimating indoor air concentrations and associated health risks from subsurface vapor intrusion into buildings. These models were based on the analytical solutions of Johnson and Ettinger (1991) for contaminant partitioning and subsurface vapor transport into buildings. Since that time, revisions to the models have been made and a series of new models have been added.

Model revisions include new values of intermediate variables for estimating the soil vapor permeability and the degree of water saturation in the capillary zone above the water table. In addition, new human health benchmarks have been added for some chemicals and revised for others. Finally, a series of automatic checks have been added to the models to prevent the use of inappropriate initial soil or ground water contaminant concentrations (i.e., soil concentrations greater than the soil saturation concentration or ground water concentrations greater than the solubility limit). The 3-phase soil contamination models listed below theoretically partition the contamination into three discrete phases: 1) in solution with water, 2) sorbed to the soil organic carbon, and 3) in vapor phase within the soil air-filled pores. The 3-phase models replace the old models previously available on this website. These models have been constructed in both Microsoft® Excel and Lotus® 1-2-3 and are applicable when NAPL is not present in subsurface soils or in ground water.

In addition to the 3-phase models discussed above, two new models have been added allowing the user to estimate vapor intrusion into buildings from measured soil gas data. These models are also constructed in both Excel and Lotus 1-2-3 and are included in the 3-phase model zip files listed below. The User's Guide also shown below covers use of both the 3-phase models and the soil gas models.

When NAPL is present in soils, the contamination includes a fourth or residual phase. In such cases, the new NAPL models

listed below can be used to estimate the rate of vapor intrusion into buildings and the associated health risks. The new NAPL models use a numerical approach for simultaneously solving the time-averaged soil and building vapor concentration for each of up to ten soil contaminants. This involves a series of iterative calculations for each contaminant. Because of the limitations of Lotus 1-2-3, the NAPL models are available only in Excel. The NAPL model User's Guide that accompanies the new models is also listed below.

Finally, a new fact sheet has been constructed that gives the procedures used to correct the Henry's law constant of a chemical for the actual soil or ground water temperature. The procedures in the fact sheet are the same as those used in the 3-phase models for correcting the Henry's law constant. These procedures and calculations can be used when adding new chemicals and associated chemical properties to those already included in the models.

User's Guide for the 3-Phase System Models and the Soil Gas Models:

User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings (Revised) [PDF (683KB) 98 pages]



3-Phase System Models and Soil Gas Models:

Excel zip file
ZIP (201 KB)

Lotus zip file
ZIP (939 KB)

User's Guide for the NAPL Models:

User's Guide for the NAPL-SCREEN and NAPL-ADV Models for Subsurface Vapor Intrusion into Buildings [PDF (64KB) 17 pages]



NAPL Models (Excel Only) and Important Readme File:

NAPL zip file
ZIP (1,064 KB)

Fact Sheet for Correcting the Henry's Law Constant for Temperature:
[PDF (186 KB) 9 pages]

In Rockford, no response

'We didn't want to be a buttinski,' EPA official says

By **Mark Obmascik**
Denver Post Staff Writer

Monday, January 07, 2002 - ROCKFORD, Ill. - State regulators knew in the mid-1980s that strong bands of industrial pollution flowed beneath hundreds of homes here. In 1993, officials finally decided to check inside some homes for toxic gas.

They found dichloroethylene gas.

They found tetrachloroethylene gas.

They found trichloroethylene gas.

They found trichloroethane gas.

If the same levels of gas had been found inside homes in Colorado or Massachusetts, state governments there would order major decontamination work.

But in Illinois, where state regulators worked at the behest of the U.S. Environmental Protection Agency, there was another reaction.

They did nothing.

"We didn't want to be a buttinski," Chicago regional EPA official Russell Hart said. "We don't want to be shriekers or alarmists. . . . We don't want to be a meddling influence in their life."

Rockford residents expressed shock that the government found toxic gas in neighborhood homes but decided against a cleanup.

"I've been raising four kids here," said Bob Hallman, 45. "My health's been deteriorating. My neighbor had a brain tumor. They found something in these homes and didn't tell us?"

The short answer is yes.

The longer answer involves government turf battles and differing regulatory views of the same health risk.

An industrial city of 150,000, Rockford became one of America's largest Superfund sites in the 1980s, when solvents were discovered polluting hundreds of private home and business wells.

Today, 10 square miles of the city lie within Superfund boundaries, and regulators believe pollution flows from at least 17 factories and dumping sites. More than 800 homes with solvent-contaminated wells have been hooked up to safe central water supplies, but the health of 1,885 solvent-exposed people still is regularly checked by the federal government.

After most Rockford homes with polluted wells were given clean water, the federal government transferred the main supervisory role over the Superfund site to Illinois state officials, who so far have decided to let almost all contamination remain beneath Rockford homes.

In August and December 1993, state regulators, responding to growing evidence of vapor threats in other contaminated sites, decided for the first time to check for toxic gas inside homes atop the polluted Rockford plumes.



Bob Hallman, one of many Rockford, Ill., residents mad about government response to toxic-gas problems.

They found plenty.

In one suburban neighborhood of \$200,000 homes, one solvent, TCA, was found in the air of all 14 sampled homes, and PCE was in eight of 14 homes.

Two miles away, in a working-class neighborhood of \$50,000 homes, solvent vapors were found in three of six sampled homes.

(For privacy reasons, state regulators declined to list contamination levels in individual houses.)

In both neighborhoods, toxic gas contaminated homes at levels that usually would trigger EPA cleanups - and always would require cleanups in tough-on-toxins states such as Colorado and Massachusetts.

EPA and Colorado set toxic vapor guidelines that assume people spent almost all their time at home; the idea is to protect invalids and stay-at-home babies. Massachusetts has similar guidelines, but also calls for gas cleanups, even at low pollution levels, whenever possible.

Illinois state officials, however, rely on health guidelines four times more lenient for TCE, two times more lenient for PCE and 150 times more lenient for DCE.

As a result, no cleanups - and no more tests of other homes - ever were ordered.

"Although we found detections of (industrial chemical vapors), we felt these levels were protective of human health," said Jerry Willman of the Illinois Environmental Protection Agency.

There may be change coming, though. After The Denver Post asked how agencies allowed levels of these vapors to remain unchecked in Rockford, state officials said they now hope to test more homes.

"We're working with U.S. EPA on this issue," said Virginia Wood of Illinois' environmental agency. "We're looking back on this site."

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Despite bill of health, town's threat lingers

By **Mark Obmascik**
Denver Post Staff Writer

Monday, January 07, 2002 - ROSCOE, Ill. - The 11000 block of Wild Deer Trail has suffered more than its share of sickness.

At the Brice home, Patti, 42, needed chemotherapy, open heart surgery and a seven-month hospital stay to beat back a near-fatal mix of lupus, hepatitis, thrush and pericarditis. Meanwhile, her 12-year-old twin daughters battled grand mal seizures.

Two houses away, Matt O'Brien, 10, was stricken with non-Hodgkins lymphoma.

Across the street, Wally Houck, 31, developed a fist-sized malignant brain tumor. His cat, Benson, had a brain tumor, too.

The federal Centers for Disease Control and Prevention says these neighbors had one thing in common: Beneath their homes trickled a strong plume of the industrial solvent TCE.

After being questioned by The Denver Post, U.S. Environmental Protection Agency officials now concede that they should check whether these homes are being exposed to toxic gas wafting up from the underground pollution.

They also admitted that their prior investigation of neighborhood pollution falsely concluded that solvent vapors posed no health risk.

"We should assess it. We should get in touch with the Department of Public Health," said Chris Black of the Chicago regional EPA office. "Right now, we don't have any money allocated for this. The wheels of government turn slowly."

Roscoe is an example of a contaminated neighborhood that EPA believed was cleared of any health threat years ago.

But the long-ago environmental work at Roscoe - like decontamination projects at dozens of other similar neighborhoods across the nation - now may have to be re-examined because of new knowledge about toxic vapors.

Two decades ago, no homeowners knew the 11000 block of Wild Deer Trail was polluted.

Many moved to this rural town of 2,100, just seven miles south of the Wisconsin line, to get away from urban trouble. With the quiet of small-town life came a reliance on private home wells for drinking water.

The neighbors on Wild Deer Trail drank whatever flowed through their groundwater.

By the early 1980s, homeowners complained more and more about stinky, foul-tasting water. When the county tested home wells, they found TCE at levels up to 400 times worse than drinking water standards allow. All told, public health officials found 100 homes contaminated with unsafe levels of TCE, TCA and DCE.

An investigation traced the problem a half-mile uphill from the subdivision, where the town's largest employer, the Warner Electric Brake and Clutch Co., leaked a 1,200-foot-wide stream of toxic



Wally Houck of Roscoe, Ill., has a brain tumor linked to an industrial solvent that ran under his home.

chemicals from unlined industrial lagoons.

The polluter started giving residents bottled water in December 1983. But many homeowners continued to use their home wells for bathing, not realizing that a typical 10-minute shower exposed them to 30 gallons of solvent contamination. The chemical dose from a single morning shower could equal the dose from two weeks of drinking from the tap.

Plus, homeowners likely were exposed to more toxic gas seeping directly into their homes from polluted groundwater, an EPA computer model now indicates.

Homeowners with contaminated wells eventually were hooked up to a new supply of safe water.

Because residents no longer drank pollution, EPA assumed the health threat was gone. So the agency decided in 1991 to let the vast majority of remaining contamination simply remain in the ground.

That meant a band of pollution, more than one mile long and a quarter-mile wide, lingers today beneath 100 homes. It's one of dozens of "monitored natural attenuation" plumes, pollution that EPA lets rot underground because the agency believes it would be too expensive to decontaminate.

(Warner Electric, a privately owned company, did agree to pump and treat polluted groundwater near the very end of the plume, after the contamination passed beneath the vast majority of homes. When asked to comment, a company executive hung up the phone on a Denver Post reporter.)

A January 1999 report by EPA engineer Bryan Holtrap concluded that homeowners are not being exposed to toxic gas.

But after The Denver Post asked about evidence of high contamination remaining beneath the neighborhood, Chicago regional EPA officials said the 1999 report wrongly ignored the threat of indoor air pollution. The official who did the 1999 report has left EPA and could not be reached for comment.

Residents said they now want their homes tested for gas.

"I can't say for certain that my brain tumor was caused by the pollution, but I don't think it would be wise to rule it out," said Houck, a computer worker who now is 38. "We've had so many health problems here. We were so glad to have the problems with the water solved. Now we should think about the other problems. We should be concerned about the air."

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Pressure by Indiana neighbors prompts skeptical EPA to act

By Mark Obmascik
Denver Post Staff Writer

Monday, January 07, 2002 - ELKHART, Ind. - Lorna Rickard wasn't supposed to know about pollution. At age 81, she could tell tales of the Great Depression, World War II or babysitting for nine great-grandchildren, but the fine points of industrial solvent plumes escaped her.

"What I knew about pollution was what I learned in biology class in 1937," Rickard said.

It turned out that she knew more than the U.S. Environmental Protection Agency.

Leader of an Elkhart neighborhood group, Rickard suspected that vast pollution plumes from a railyard spill might be wafting industrial solvent vapors into homes above.

EPA doubted her. But with hopes of persuading Rickard to stop pestering him, an EPA official finally agreed to test the air inside some homes.



Post: Helen H. Davis

Lorna Rickard stands on railroad tracks near her Elkhart, Ind., neighborhood.

Sure enough, the government found toxic gas - enough to require the decontamination of nine homes.

"Today, I really appreciate that they prodded us on this issue. I'm glad they had us do this," said Brad Bradley of the Chicago regional EPA office.

Rickard was a retired secretary when her neighbors learned in 1986 that their groundwater was contaminated. In a city that serves as an RV construction hub, Rickard and a diverse band of factory workers, teachers and construction framers formed a group called CLEAN, or Citizens League for Environmental Action Now.

By the early 1990s, regulators determined that a swath of Elkhart had been polluted by repeated spills and leaks from the square-mile Conrail Railyard. Some wells in the area were contaminated with degreasers such as carbon tetrachloride and TCE at levels up to 1,000 times worse than drinking water standards.

More than 640 homes and businesses with polluted wells eventually were hooked up to clean city supplies. But most pollution was allowed to remain beneath the homes.

In 1998, Rickard and other CLEAN members, especially RV factory worker Mike Fitch, worried that the underground contamination might be seeping up to houses.

"My grandfather found a co-worker dead from carbon tetrachloride. He was overcome by fumes when he was cleaning out a machine chamber," Fitch said. "I knew this was really wicked stuff, and I sure didn't want it in my home."

Rickard, Fitch and other CLEAN members dogged the EPA until the agency finally agreed to test indoor air. The agency eventually found unsafe levels of carbon tetrachloride vapors in nine homes.

"I don't feel safe living in my home," said David Henderson, 52, whose house exceeded health standards for vapors. "I think the EPA should live in my house."

The agency refused to buy Henderson's home, but it did order the installation of a ventilation system

to rid the house of vapors. The system costs less than \$2,000.

Though Chicago EPA officials say they're grateful the vapor problems were detected, they do wonder how many other polluted homes across America have undetected toxic gas woes.

"I learned a pretty powerful lesson from this: You've got to consider vapors," said Bradley. "On major remediation sites, we always ask the million-dollar question: How much testing is enough? In this case, I'm glad we tested. I never thought the vapors would be an issue here. We learned otherwise."

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Wednesday, December 11, 2002

InsideEPA
All the latest environmental news**Today**

Industry Backs First-Time EPA Guide On Indoor Air Pollution From Hazardous Waste

Industry sources are supporting EPA's first-ever guidance for handling indoor air contamination that seeps into buildings from hazardous waste sites, an issue referred to as "vapor intrusion," primarily because the document is limited to residential sites and does not address commercial properties. The industry support is an about-face from initial reactions to an earlier draft of the guidance, which prompted industry officials to argue that the effort would duplicate federal requirements to protect workers.

EPA issued the draft guidance on Nov. 22, which lays out steps regulators should take to determine if there is a vapor intrusion pathway and whether the intrusion represents an unacceptable risk to public health. The guidance calls for a three-tier process, involving primary and secondary screening of a site, followed by a site-specific pathway assessment. Vapor intrusion refers to the process of toxic gases leaking into buildings from contaminated soil and groundwater.

The guidance is supposed to be used at Superfund and Resource Conservation & Recovery Act (RCRA) sites and at brownfields, and is part of the agency's effort to implement a RCRA environmental indicator (EI) for vapor intrusion. EPA uses EIs as a way to determine when a cleanup has cleared a site of the most threatening contamination. For vapor intrusion, the agency is required to have current human exposures under control at 95 percent of RCRA sites by 2005.

Originally industry sources had opposed the guidance as duplicative of requirements set in place by the Occupational Safety & Health Administration (OSHA) to regulate commercial properties. But the agency makes clear that its guidance only applies to residential sites. "OSHA and EPA have agreed that OSHA will generally take the lead role in addressing occupational exposures," the guidance states.

An industry source says that companies that were worried about duplicative federal requirements are supportive of the EPA guidance now that it only applies to residential properties, calling vapor intrusion a "legitimate path of concern."

Companies are "very pleased" that the agency is allowing OSHA to continue to handle commercial properties, the source says, because industry has already developed monitoring and informational programs to handle vapor intrusion at such sites. And the source says that residential standards would be too strict for commercial properties because individuals are at home for longer periods than at work, requiring a lower threshold than at a place of employment.

But there is some concern that EPA's guidance is too conservative, the source adds. The guide sets a risk-based standard for the concentration of indoor air contaminants that would trigger regulations of the waste stream. "[T]his guidance provides targeted indoor air concentrations set at 10^{-4} , 10^{-5} , and 10^{-6} (incremental individual lifetime cancer risk) levels . . .," the document states.

But the industry source says this flexibility will likely result in regulators choosing the most conservative concentration to regulate indoor air contamination. This uncertainty concerns industry officials who want to know what is expected of them, the source says. "Unfortunately, that leaves you wondering," and responsible parties are "less certain of what you're expected to do."



United States
Environmental Protection
Agency

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www.epa.gov/osw

Evaluating the Vapor Intrusion into Indoor Air

The Environmental Protection Agency (EPA) issues a draft guidance to help determine if the vapor intrusion exposure pathway poses a significant risk to human health.

Action

EPA issues a draft guidance that provides current technical and policy recommendations on determining if the vapor intrusion pathway poses an unacceptable risk to human health at cleanup sites. This guidance is not intended to provide recommendations for delineating extent of risk or eliminating risk.

The guidance is suggested for use at the Resource Conservation and Recovery Act (RCRA) Corrective Action sites, National Priorities List and Superfund Alternative sites and Brownfields sites, but is not recommended for use at Subtitle I Underground Storage Tank sites at this time.

EPA recommends that program implementers consider the use of this draft guidance as a screening approach in implementing the RCRA and CERCLA programs. Although the document is still in draft and EPA is requesting comment on it, it has gone through extensive agency review, and believe it is a technically sound product. While we hope to receive useful comments that will result in improvements when the draft is finalized, we believe the document in its current state provides the best guidance and information currently available on these issues. Implementers should remember, of course, that this document serves as guidance only and should not be construed in any fashion as mandatory.

Vapor intrusion is a rapidly developing field of science and policy. This draft guidance is intended to aid in evaluating the potential for human exposure from this pathway given the state-of-the-science at this time. EPA will continue to explore this area in efforts to improve the state-of-the-science of this complex exposure pathway. A workgroup of EPA and State representatives is currently being organized to evaluate this pathway over the next several years. As the state-of-the-science improves, this guidance will be revised as appropriate.

EPA and State site managers are encouraged to contact EPA's Office of Solid Waste to join the workgroup and/or provide the workgroup with relevant site information.

that can be added to the Office of Solid Waste and Emergency ^{Response} database to facilitate these efforts.

Background

In December 2001, EPA issued the draft RCRA Environmental Indicator Supplemental Guidance for Evaluating the Vapor Intrusion Into Indoor Air Pathway. The current guidance replaces the 2001 document, but does not replace the State guidance.

Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying buildings. Volatile chemicals in buried wastes and/or contaminated groundwater can emit vapors that may migrate through subsurface solid and into air spaces of overlying buildings.

In extreme cases, the vapors may accumulate in dwellings or occupied buildings to levels that may pose near-term safety hazards, acute health effects or aesthetic problems. In most cases, however, the chemical concentrations are low, or depending on site-specific conditions, vapors may not be present at detectable concentrations.

For More Information

This fact sheet, the *Federal Register* notice, and other documents related to this action are generally available on the Internet when the rule is published. See: <<http://www.epa.gov/epaoswer/hazwaste/recycle/fertiliz/index.htm>>. For additional information, contact the RCRA Call Center. Callers within the Washington Metropolitan Area must dial 703-412-9810 or TDD 703-412-3323 (hearing impaired). Long-distance callers may call 1-800-424-9346 or TDD 1-800-553-7672.

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CITY OF ROCKFORD AGREES TO PROCEED WITH CLEANUP AT SOUTHEAST ROCKFORD GROUNDWATER CONTAMINATION SITE

U.S. Environmental Protection Agency (EPA) Region 5, U.S. Department of Justice (DOJ), and Illinois Environmental Protection Agency (IEPA) have recently lodged a consent decree with the U.S. District Court for the Northern District of Illinois, Western Division, in which the City of Rockford, IL, agrees to proceed with the cleanup of the second of three units at the Southeast Rockford Groundwater Contamination site.

The site, which is on the Superfund National Priorities List, contains high levels of hazardous chlorinated volatile organic compounds in the ground water. Since 1989 EPA has provided bottled water, drinking water filters, and extension of the city's municipal water mains to nearly 600 residences.

Under the consent decree, lodged on January 21, the city agrees to:

- Construct new municipal water main extensions to allow for residential and commercial potable water service to an area roughly south of Harrison Ave., west of 24th St., north of Sandy Hollow Rd., and east of the Rock River;
- Construct and determine locations for 9 new ground-water monitoring wells, in addition to the 26 wells the city already has in place;

- Maintain an enhanced ground-water monitoring and sampling program for the foreseeable future, or until EPA-specified clean drinking water levels are attained; and

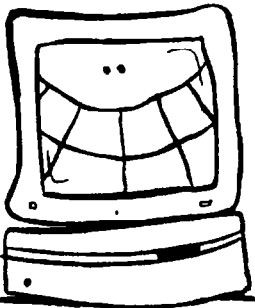
- Establish institutional controls, including a system for notifying parties purchasing property from individuals or businesses that have previously refused city water-service connections.

"The cleanup work to be performed under this order is designed to address the concerns many area residents and businesses have shared with EPA," said regional Superfund Director William Muno. "We are optimistic that most of the work will be completed, promptly and economically, during the 1998 construction season."

Written comments on the consent decree, during the 30-day comment period to be announced in the Federal Register, may be sent to: Environmental Enforcement Section, U.S. Department of Justice, P.O. Box 7611, Ben Franklin Station, Washington, DC 20044.

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EPA model based on one test

National toxic-gas cleanup depends on faulty analysis of Denver apartment

By Mark Obmascik
Denver Post Staff Writer

Monday, March 18, 2002 - Beyond the yellow brick wall, down three carpeted steps and inside a dingy hallway stands the dark wood door of Summit Place Apartment No. 3-101. The U.S. government knocked here five years ago and concluded - somehow - that thousands of Americans were safe.

This two-bedroom, one-bathroom apartment in southeast Denver is the only place where the Environmental Protection Agency has tried to verify the accuracy of a key government tool - the computer model that estimates whether homeowners and tenants are breathing dangerous levels of toxic gas.

Regulators have used the computer model to exempt polluters from cleaning up hundreds of neighborhoods across America. In a few cases, the model did work and helped launch home decontaminations.

State regulators say the model is so unreliable they won't use it. Scientists in Seattle and England found the model repeatedly underestimated the health risks of indoor air pollution.

And another EPA review found model-based contamination standards in Connecticut, Massachusetts and Michigan were so lenient that they failed to protect public health up to 86 percent of the time.

Despite all those doubts, EPA officials said they've field-tested their computer model just once - with a \$2,400 study of Apartment 3-101.

EPA administrators said the model worked there.

To make it work, however, national EPA consultants assumed the Denver apartment was built atop sand.

But that's not so, a top local EPA Superfund official now says. The switch made it easier for the model to appear accurate.

The national EPA consultant also changed nine variables in the model that EPA typically won't let regulators alter.

Does the EPA model protect public health?

"I think we're doing a pretty good job," said Matt Hale, deputy director of EPA's Office of Solid Waste in Washington, D.C. "I'm not saying there's nowhere we've missed. It's an issue we need to pay more attention to."

At toxic-waste sites across the country, EPA's computer model is the main way state and federal

regulators decide whether industrial solvent vapors are seeping into homes and businesses at levels that make people sick.

Several heavily industrialized states - including California, Michigan, Ohio, Pennsylvania and Texas - concede they've never verified the accuracy of the model, even though they've used it to rule out toxic cleanups of thousands of homes at hundreds of polluted sites.

The model was invented by two Shell Oil Co. researchers during the \$2 billion Superfund cleanup of the Rocky Mountain Arsenal north of Denver.

Shell wanted to limit its decontamination spending there, so company researchers Paul Johnson and Robbie Ettinger created a computer program that, based on groundwater pollution levels, estimated the amount of contaminated gas in a house.

Johnson and Ettinger announced their invention in 1991. EPA endorsed it seven years later, and directed state and federal regulators to download a version of it from the agency's website.

Poor reviews, however, began trickling in.

At two sites in Colorado, in Massachusetts, Washington and in Manchester, England, measurements of pollution proved the model wrong.

In January, The Post reported that one of the inventors of the computer model, Robbie Ettinger, conceded that his creation appeared to significantly underestimate toxic gas pollution in southeast Denver's Redfield neighborhood.

Later that month, a Denver EPA hydrogeologist, Helen Dawson, released a study showing that three states adopted toxic-gas standards so lenient that they often fail to protect public health. Michigan, Connecticut and Massachusetts all used the EPA model to set their pollution standards.

EPA's study found that Michigan's model-based regulations failed to detect unsafe levels of toxic gas in homes 86 percent of the time. Connecticut's failure rate was 75 percent, and Massachusetts' was 36 percent.

With all these field tests casting doubt on the toxic-gas model, The Post asked EPA to provide copies of all studies that verified its accuracy.

EPA responded with a seven-page report on Apartment 3-101.

"This is the only one we're aware of," said Hale with EPA in Washington.

That home stands above a plume of the industrial solvent DCE leaking from the Colorado Department of Transportation headquarters at 4201 E. Arkansas Ave. Five apartment buildings and 27 single-family homes required decontamination.

The January 2000 study was conducted by EPA consultant Craig Mann. He died last year, and EPA officials said last week they were unfamiliar with many details of the review.

Mann reviewed 15 air samples from inside Apartment 3-101 and 13 groundwater samples collected nearby.

The model usually is used by regulators when they know how much groundwater pollution is outside the house, but don't know how much toxic gas is in the house.

Regulators rely on the model to convert known outdoor water contamination into estimated indoor vapor contamination.

For this test, though, the consultant had 28 air and water samples. He knew exactly what results the model was supposed to produce.

The consultant then made an unusual decision. He decided that apartment No. 3-101 was built atop sand.

It isn't, said Barry Levene, the Denver regional EPA official who supervises Colorado Superfund cleanups.

"I would not classify it as sand. It's more like clay," Levene said.

The Colorado state worker who supervised the CDOT cleanup also questioned the sand classification.

"I'm not sure that's actually the case there," Jim Paulmeno said. "At the upper levels, I don't remember sand. It was compacted clay."

That difference is key, because the model assumes that sand allows much more toxic gas inside homes than clay soils do. That reclassification would help the model overcome its chief reported shortcoming - that it underestimates the amount of gas seeping into homes.

The EPA consultant also changed nine technical variables that regulators using the model typically can't change. These variables include building size, the thickness of soil layers beneath the building and the difference in indoor and outdoor air pressure.

After those changes, the study concluded that predicting how much vapor gets into a building relies on "complex physical and chemical processes," many of them "not well understood."

"Nonetheless," the study said, "calibration of the model for specific site conditions using the protocol described above can result in credible predictions."

But Colorado's top cleanup official on the CDOT pollution said he's glad the state relied on direct air tests instead of modeling to guide the cleanup.

"There are just so many variables with this model," Paulmeno said. "It's different and more difficult than the standard groundwater models. There are so many variables and more uncertainty in the process."

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